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ScienceDirect

Energy Procedia 61 (2014) 290 – 293

Energy Procedia

The 6th International Conference on Applied Energy – ICAE2014

Potential of Saving Energy Using Advanced Fuzzy Logic Controllers in Smart Buildings in Subtropical Climates in Australia

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Abstract

Subtropical Regions in Australia are associated with high demand for air conditioning throughout the long Summer which leads to a high energy consumption and consequently high greenhouse gas (GHG) emissions which has a high negative impact on the environment. Using conventional controllers in Building Management Systems (BMS) whose functions are based on ON/OFF, temperature control and in some cases humidity control is not the ultimate solution to save energy. The reason behind the above fact is that, conventional controllers do not take into account real time events such as the number of occupants, indoor air quality (IAQ), natural light illuminations and etc dislike Fuzzy logic based controllers. In the last decade there is a high interest in researching Fuzzy logic based controllers as they have the ability to save energy while maintaining indoor comfort level. In this article a general review on Fuzzy logic based controllers is presented, focusing on the role of technology in saving energy, and its potential in subtropical Central Queensland, Australia. The issues of past and present techniquesare highlighted and discussed accordingly.

Peer-review under responsibility of the Organizing Committee of ICAE2014

Keywords: Subtropical, Building management Systems (BMS), Controllers, Fuzzy base controllers

1. Introduction

Building management Systems (BMS) are control systems that satisfy buildings, occupants' requirements for comfort while keeping energy consumption during building operations minimum. BMS is used to monitor and control heating, ventilation, and air conditioning (HVAC), lighting, cold and hot water supplies, firefighting systems, lifts, escalators and etc.

A concept which recently has been repeatedly discussed is smart buildings. Smart building is a building that can achieve a significant energy savings by utilizing advanced control systems, technologies, materials, appliances, electrical systems, plumbing, HVAC system, and etc. Thus, there is no common

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Peer-review under responsibility of the Organizing Committee of ICAE2014
doi:10.1016/j.egypro.2014.11.1110

agreement which is the most energy efficient technique of controlling thermal comfort for various types of buildings [1]. The presence of occupant and their behavior in buildings have a significant influence on HVAC, lighting and appliances load as well as the building controls [2].

Fuzzy based control systems which are able to adjust indoor comfort set points when buildings are occupied or unoccupied, leads to energy conservation set points and able to shut down part of the building systems if necessary. Around the world, there are several ways of controlling indoor thermal conditions in buildings. A vast number of control strategies and techniques have been proposed, and searched in the past two decades due to rapid development of computers, controllers, sensors and communication techniques [3]. These research activities were focused on controllers' technical performance including control strategies and communication protocols [4-7]. Australian subtropical regions' buildings' occupancy based control strategies (Fuzzy based) are not included in its management systems. Therefore this article, presented the potential of using a high-level control strategy in building within the Subtropical Climates, Central Queensland regions, in Australia.

2. Fuzzy Supervisory Control

Fuzzy logic based control has gained momentum in control engineering and has been used in several control fields. In most of these applications, PID controllers are still in use in combination with fuzzy logic which is considered as a multivariable supervisory controller of the PIDs [8]. Figure 1 shows, the most common fuzzy supervisory controller's frameworks which are used in many control fields where the Fuzzy set contains fuzzy loops which may individual or coupled with PID with one or more inputs and outputs. Also the fuzzy block represents high level control strategy and the PID represents the conventional control system [9].

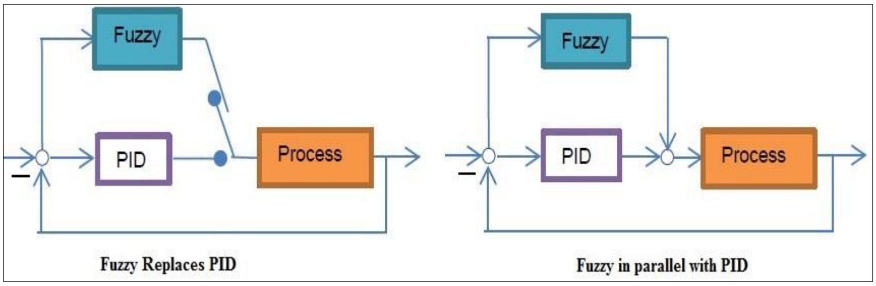

Fig. 1. Fuzzy set contains fuzzy loops coupled with PID [9]

In Figure 1, the fuzzy based controller module can be used to adjust existing or old conventional controller PID parameters. PID controller are used to control non-linear processes which gives satisfactory performances within a small range of operating conditions while the fuzzy based controller can be used to tune the parameters of the lower level controller in order to improve its performances. This strategy allows more fuzzy outputs to the outputs of the PID controller in order to restore its normal states [9].

3. Fuzzy Supervisory Control

To determine the amount of energy savings of a BMS controlled building, the building energy load should be determined and compared using conventional PID controllers and then using Fuzzy based controllers. Building parameters are governed by two thermal balance equations. Equation 1 due to total heat gain and Equation 2 due to sensible heat gain [10].

$$\frac{dT}{dt} = \frac{UA}{cap}(T_{amb} - T_{set}) + \frac{\dot{m}_{vent} C_{pair}}{cap}(T_{vent} - T_{set}) + \frac{\dot{m}_{\inf} Cp_{air}}{cap}(T_{\inf} - T_{set}) + \sum Q_{gain} \quad (1)$$

$$\sum \mathrm{Q_{gain}} = \mathrm{Q_{lights}} + \mathrm{Q_{equip}} + \mathrm{Q_{people}} + \mathrm{Q_{infl}} + \mathrm{Q_{vents}} + \mathrm{Q_{solar}} \quad (2)$$

Where T is zone temperate (ºC), U is building loss coefficient ($kW/hr.m^2.C$), A is space over all area (m^2), cap is building capacitance (kW/C), T_{set} is Space set temperature (ºC), $\dot{m}_{vent}$ is ventilation air mass flow rate (kg/hr), C_{pair} is specific heat of building air (kW/kg.ºC), T_{vent} is temperature of ventilation air (ºC), $\dot{m}_{inf}$ is mass flow rate of infiltration air (kg/hr), T_{inf} is temperature of infiltration air (Cº), Q_{gain} is sensible heat gain (kW), Q_{light} is heat gain resulting from lights, Q_{equip} is heat gain resulted from equipment used in the building including computers and printers (kW), Q_{people} is sensible heat gain resulted from people (kW), Q_{inf} is sensible heat gain from infiltration (kW), Q_{vent}s is sensible heat gain due to ventilation and Q_{solar} is heat gain due to sun radiation (kW).

Equation 3 governs building heat balance due to sensible heat gain.

$$\frac{d\omega}{dt} = \frac{\dot{m}_{\inf}}{\rho V}(\omega_{vent} - \omega) + \frac{\sum \omega_{gain}}{\rho V} \quad (3)$$

Total building sensible heat gain is calculated using Equation 4.

$$\sum \omega_{\mathrm{gain}} = \omega_{\mathrm{people}} + \omega_{\mathrm{infl}} + \omega_{\mathrm{vents}} + \omega_{equip} \quad (4)$$

Here ω is heat gain due to air moisture content (kW), ρ is density of building air (kg/m^3), V is building volume (m^3), ω_{gain} is total heat gain due to moisture content of the air (latent), ω_{people} is latent heat gain from people (kW), ω_{inf} is latent heat gain from infiltration (kW), ω_{vent} is latent heat gain due to ventilation (kW) and ω_{equip} is latent heat gain using equipment and cooking (kW).

The potential of energy saving E_{saved} can be evaluated based on a comparison between a conventional controller system and a Fuzzy based system which expressed by equation 5 [11].

$$E_{Saved} = E_{\mathrm{conv}} - E_{fuzz} \quad (5)$$

Where E_{Conv} is conventional system electric power (kW)and E_{Fuzz} is Fuzzy based control system electric power (kW).

In addition the controlled building consumed energy using conventional PID Controllers can be estimated using equation 6.

$$E_{conv} = \omega_{gain} + E_{light} + E_{equip} \quad (6)$$

Where E_{light} is energy needed to power lighting system and Equip is energy needed to power other $E_{quipments}$ operated in the building using conventional control system.

Where the building consumes energy using Fuzzy logic based controllers is calculated as in 7.

$$E_{fuzz} = \omega_{gain} + E_{light} + E_{equip} \quad (7)$$

4. Discussion

Most of BMS control strategies researched for an application in buildings have been mostly devoted to scheduling, tuning or optimization of PID or other local controllers' parameter. Variable set point setting is the most use technique which is very difficult task for large building operators.

The aim of energy savings performance analysis is to determine the fuzzy based controllers systems'' control strategies in conjunction with conventional PID controllers. The equations mentioned in this paper will allow architects, design engineers, business owners and developers to design and deliver an optimum control system that can compete with the conventional PID control systems and to provide suitable indoor control solutions in Australian subtropical regions' commercial buildings. Yet energy saving using advanced based fuzzy controllers has not been assessed under influence of the subtropical climate which will be done for Central Queensland, Australia.

5. Conclusion

Achieving a comfortable and healthy indoor air environment is essential. In the literature it is found that the objective of building management system (BMS) is to deliver efficient building operation at reduced energy while maintain comfortable working environment. The fuzzy based controller proved significant advantages in processes with intensive nonlinearity and is superior to the digital controller. Because this technology is an add-on to existing conventional control systems, it also can open new application fields for fuzzy logic and fuzzy control in the market of building automation and building management with less installation cost.

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